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A New Semidwarf Mutant in a Long-Grain Rice Cultivar[1]

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ABSTRACT

The inheritance of an induced short stature mutant, Short Labelle, recovered from the rice (*Oryza sativa* L.) cultivar Labelle was investigated. In crosses with Labelle and 'Lebonnet', the F_1 plants were tall, and the short stature characteristic segregated as a single recessive factor in the F_2 generation. Progeny tests in a cross with ED7 indicated Short Labelle carried semidwarfing gene nonallelic to the *sd*$_1$ gene in ED7. F_1 sterility and F_2 segregation for sterility was observed in the Labelle and Lebonnet crosses. Pleiotropic effects on grain and mesocotyl lengths were noted. In 2 yrs of multiple location testing the agronomic characteristics of Short Labelle were similar to Labelle, although Short Labelle yields were generally lower. However, because it has a semidwarfing gene nonallelic to the *sd*$_1$ source, Short Labelle may be a useful germplasm source for rice improvement.

Additional index words: **Short stature, Inheritance, Germplasm, Induced mutation, *Oryza sativa* L.**

THE semidwarf plant type has been extensively utilized in the improvement of rice [*Oryza sativa* (L.)] cultivars throughout the world (3,5). In the majority of cases, rice breeders have relied on 'Dee-geo-woo-gen' (or 'TN-1' and 'IR-8') germplasm as a source of semidwarfism (5). Development of additional semidwarfing gene sources is desirable to reduce the risk of genetic vulnerability and to broaden the germplasm base for rice cultivars. Induced mutation has been successfully utilized to generate semidwarf rice cultivars and germplasm and may serve as one mechanism to develop new sources of semidwarfism in rice (7). This study describes the inheritance, characteristics, and agronomic performance of another source of semidwarfism in rice.

MATERIALS AND METHODS

In 1978 a single short-stature X_2 plant was found at the Rice Research Facility of the University of California at Davis, California. The X_2 generation was grown from bulk X_1 generation seed provided by C.N. Bollich, USDA-ARS, Beaumont, TX, who had subjected seeds of the tall long-grain rice cultivar 'Labelle' (LBLE) to ^{137}Cs radiation. The parent cultivar has been described (1) and is one of the most extensively grown rice cultivars in the southern USA. This short-stature mutant was an average of 23 cm shorter at maturity than LBLE and was experimentally designated "Short Labelle" (SLBL). Crosses were made to the parent cultivar LBLE, the tall southern long-grain cultivar 'Lebonnet' (LBNT), and the medium-grain line ED7 which carries the *sd*$_1$ gene present in 'Calrose 76' and other recent California semidwarf rice cultivars (7). The F_1 and F_2 pop-

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ulations of SLBL/LBLE and SLBL/LBNT were space transplanted (30 × 30 cm) at the Rice Research Station at Crowley, Louisiana in 1983. The SLBL/LBLE and SLBL/LBNT F_1 populations contained 33 and 19 plants, respectively. The SLBL/LBLE and SLBL/LBNT F_2 populations consisted of 114 and 112 plants, respectively. Plant heights were determined in the progenies of these crosses to elucidate the genetic control of the short stature characteristic of SLBL.

Agronomic characteristics of SLBL and LBLE were determined in replicated yield tests at multiple locations in the southern USA. In 1981 they were evaluated at four Arkansas locations in randomized complete block experiments with four replications at each location (6). Agronomic data were collected from drill-seeded six row plots (1.1 × 4.9 m) and yields estimated from harvest of the center 2.6 m^2 (four rows × 3.7 m). The seeding rate was 112 kg ha^{-1}. In 1982 SLBL and LBLE were included in the Cooperative Regional Uniform Rice Nursery and evaluated by researchers in Arkansas, Louisiana, Texas, and Mississippi (2). The experimental design at every location was the randomized complete block with four replications. Plot size and data collection procedures were similar to those in Arkansas in 1981, except that the Louisiana test was water-seeded at 168 kg ha^{-1}, and yield estimates in Arkansas and Texas were calculated by harvest of 1.3 m^2 (two rows × 3.7 m) from the center of each plot.

RESULTS AND DISCUSSION

Inheritance of Semidwarfism

The SLBL/LBLE F_1 plants in the transplant nursery at Crowley in 1983 were tall with a mean height of 1.11±0.01 and range of 1.05 to 1.22 m. The SLBL/LBNT F_1 plants were tall and had a mean height of 1.00±0.02 and range of .92 to 1.05 m. Comparisons to respective parents were not possible as they were inadvertently omitted during transplanting, but the tall heights observed in the F_1's were comparable to tall male parents planted elsewhere in the nursery. The SLBL/LBLE and SLBL/LBNT F_2 plants had mean heights and ranges of 1.02±0.02 and .72 to 1.21 m, and 1.03±0.02 and 0.85 to 1.23 c, respectively. The tall F_1 populations and the bimodal frequency distributions for plant height and the satisfactory fit to a 3 tall:1 short ratio for both F_2 populations indicate a single recessive gene is controlling plant height (Table 1). The recessive nature and segregation for semidwarf plant type has been observed in several other crosses with SLBL in the Louisiana rice improvement program.

In the 1979–1980 winter nursery in Hawaii, the mean height of 9 SLBL/ED7 F_1 plants was 0.88±0.02 m compared to 0.75±0.02 and 0.74±0.03 m for 13 and 12 plants of the parents SLBL and ED7, respectively. Although they were only 0.88 m, the F_1 plants were considered tall because the height of all lines was generally reduced in the Hawaii winter nursery; for example, the tall cultivar Mars was only 0.88±0.02 m in the same test. In the subsequent F_2 generation grown at Davis in 1980, segregation for tall (1.10 to 1.20 m) and semidwarf (0.80 to 0.90 m) heights were evident. Because of competition effects between tall and short plants, segregation ratios were not determined on individual F_2 plants but were deferred to F_3 progeny tests in 1981. In the F_3 tests, 10 to 15 plants were grown from each F_2 plant. The F_2 segregation ratios as determined from the F_3 progeny tests are shown in Table 2. The data did not fit the expected 1:4:4:4:2:1 segregation, but with the small F_3 population misclassification would be anticipated amongst the three types which could produce tall plants (types 1, 2, and 3 in Table 2). Misclassifications also would be anticipated among Types 4 and 5. Therefore Types 1, 2, and 3 were pooled and Types 4 and 5 were pooled for testing the 9:6:1 ratio. Because of the absence of doubledwarf lines, the pooled segregations did not fit the 9:6:1: ratio. However, the data provided satisfactory fit to a 9:6 ratio which is the expected ratio assuming the doubledwarf plants failed to survive in the relatively deep (0.15 to 0.20 m) water in the F_2 experiment. In several F_3 lines segregation was observed for putative doubledwarf plants which were 0.10 to 0.15 m shorter than semidwarf plants. Progeny tests were conducted in 1982 on each plant from 13 such segregating F_3 rows. The F_4 progenies of each suspected F_3 doubledwarf (total of 18 F_3 plants tracing back to 13 F_2 plants) did not show segregants from the doubledwarf plant height (Table 3). The F_4 progeny tests of sister plants in the 13 F_2-derived families revealed that the original F_2 genotypes must have been 8 $Sd_asd_aSd_bsd_b$:5 $sd_asd_aSd_bsd_b$, where sd_a and sd_b represent recessive semidwarf genes, one of which is sd_1. Since the sd_1 gene in the ED7 parent and the new *sd* gene in SLBL have similar phenotypic effects on reducing plant height, it was not possible in the subsequent generations to determine which homozygous semidwarfing pair of alleles was carried by semidwarf plants from crosses. However, from these observations, it was concluded that the semidwarfing gene in SLBL is nonallelic and segregates independently of the sd_1 gene. The new

Table 1. Number of F_2 plants in two height classes for two crosses between Short Labelle and tall parents, grown at Crowley, LA in 1983.

Crosses	Height class Tall (0.96–1.25 cm)	Short (0.70–0.95 cm)	χ^2 Probability (3:1)
	no. of plants		
Short Labelle/Labelle	78	36	0.10–0.25
Short Labelle/Lebonnet	83	29	0.75–0.90

Table 2. Height segregation ratios observed in F_3 progenies of Short Labelle/ED7, grown at Davis, CA in 1981.

F_3 row type	F_2 parent genotypes	Expected frequencies for two independent genes	Observed no. of F_3 rows	No. of F_3 rows from grouping similar types
1. All plants tall	$Sd_1\,Sd_1\,Sd\,Sd$	1/16	22	223
2. Segregating for tall and semidwarf	$Sd_1\,sd_1\,Sd\,Sd$ $Sd_1\,Sd_1\,Sd\,sd$	4/16	185	
3. Segregating for tall, semidwarf and doubledwarf	$Sd_1\,sd_1\,Sd\,sd$	4/16	16	
4. Segregating for semidwarf and doubledwarf	$sd_1\,sd_1\,Sd\,sd$ $Sd_1\,sd_1\,sd\,sd$	4/16	30	131
5. All plants semidwarf	$Sd_1\,Sd_1\,sd\,sd$ $sd_1\,sd_1\,Sd\,Sd$	2/16	101	
6. All plants doubledwarf	$sd_1\,sd_1\,sd\,sd$	1/16	0	0
P (9:6:1)				<0.005
P (9:6)				0.25

gene is tentatively designated sd_5, as gene symbols sd_1 through sd_4 have been previously assigned (7). Table 4 shows the heights of three doubledwarf lines in comparison to their semidwarf parent grown in Davis, CA in 1983.

Characteristics and Performance

Although SLBL and the cross SLBL/ED7 were fully fertile, some sterility (<40% seed set) was observed in the F_1 plants of crosses between SLBL and its parent LBLE, and in crosses with other southern U.S. rice cultivars. This has been surprising, particularly since SLBL is an induced mutant from LBLE. The SLBL/LBLE and SLBL/LBNT F_2 populations segregated for sterility in addition to plant height. A contingency table between plant height classes (tall, semidwarf) and sterility (>90% seed set, <40% seed set) was constructed to identify any association of this sterility with the semidwarfing gene in SLBL. Expected values for the cells were calculated based on the observed marginal values for the classes and tested for goodness of fit to the observed cell values. The χ^2 values were highly significant indicating a deviation from independence between plant height classes and sterility (Table 5). Tall sterile and short fertile cells had more plants than expected. This association did not preclude the recovery of plants in any of the four cell classes.

Brown rice grain length, width, and length/width ratio of SLBL were 6.73 ± 0.06, 1.98 ± 0.04, and 3.41 ± 0.08 mm, compared to 7.09 ± 0.08, 2.10 ± 0.07 and 3.38 ± 0.11 mm for LBLE. Reduction in kernel length is a common occurrence in many semidwarf mutants recovered in mutation breeding programs (7). Short mesocotyl lengths are also frequently associated with the semidwarf plant type (8). SLBL has a marked reduction in mesocotyl length averaging 18.1 ± 0.7 compared to 28.2 ± 1.1 mm for the parent cultivar LBLE. Reduced mesocotyl lengths can be an undesirable characteristic in drill-seeded rice by contributing to poor emergence through the soil, especially if the seed is planted at depths greater than 20 mm.

Results of 2 yrs of replicated testing at locations in the southern USA are summarized in Table 6. Plant height differences between SLBL and LBLE were quite distinctive at all test sites. The SLBL was slightly later heading than LBLE although that 2-day difference was inconsequential. In the 1981 tests, LBLE performed significantly better at two locations and averaged better than SLBL. The Clay County location was a high yielding test and SLBL yielded the same as LBLE. In 1982 testing, LBLE yielded significantly higher than SLBL at three of the four locations and overall. As Gale et al. (4) have noted, the performance of newly induced mutant genes frequently is improved when they are "cleaned-up" by transfer to different backgrounds. Whether this will

Table 3. Segregation of Short Labelle/ED7 F_4 progeny test of putative doubledwarfs (DD) grown at Davis, CA in 1982.

1981 F_3 putative DD	1982 F_4 conclusion for each putative DD	1982 F_4 segregation of 1981 F_3 sister plants: TSD*	T	TS	SD	S	DD	Probable F_2 genotype of ancestor
81/12286-DD-1, 81/12286-DD-2	Doubledwarf				3	6	2	*sdsd Sdsd*
81/12289-DD	Doubledwarf		1	5	3	3	1	*Sdsd Sdsd*
81/12334-DD	Doubledwarf			3	3	6	1	*Sdsd Sdsd*
81/12345-DD	Doubledwarf		4	6		6	1	*Sdsd Sdsd*
81/12346-DD	Doubledwarf	1		4	1	4	1	*Sdsd Sdsd*
81/11972-DD-1, 81/11972-DD-2	Doubledwarf		3	3	3	2	2	*Sdsd S*[illegible]
81/11977-DD	Doubledwarf			3	1	4	1	*Sdsd Sdsd*
81/11986-DD	Doubledwarf				7	3	1	*sdsd Sdsd*
81/12016-DD-1, 81/12016-DD-2	Doubledwarf				3	8	2	*sdsd Sdsd*
81/12040-DD-1, 81/12040-DD-2	Doubledwarf				6	1	2	*sdsd Sdsd*
81/12053-DD	Doubledwarf				4	1	1	*sdsd Sdsd*
81/12058-DD-1, 81/12058-DD-2	Doubledwarf		1	5	1	3	2	*Sdsd Sdsd*
81/12198-DD	Doubledwarf		2	2	1	2	1	*Sdsd Sdsd*

* TSD = segregating for tall, semidwarf, and doubledwarf plants; T = all plants tall; TS = segregating for tall and semidwarf plants; SD = segregating for semidwarf and doubledwarf plants; S = all plants semidwarf; DD = all plants doubledwarf.

Table 4. Mean heights and heading dates of confirmed doubledwarf lines and parents grown at Davis, CA in 1983.

Line	No. of plants	Height (m)	Heading date (days)	Genotype
81/12040-DD-1	10	0.59	91	$sd_1sd_1\ sd_5sd_5$
81/12058-DD-2	10	0.59	107	$sd_1sd_1\ sd_5sd_5$
81/12198-DD	10	0.63	94	$sd_1sd_1\ sd_5sd_5$
Short Labelle	5	0.83	101	$Sd_1Sd_1\ sd_5sd_5$
ED7	5	0.86	94	$sd_1sd_1\ Sd_5Sd_5$

Table 5. Contingency table analysis of the relationship of plant height classification and sterility in the F_2 generation of two crosses. Expected cell values are shown in parenthesis.

Cross		Fertile (>90% seed set)	Sterile (<40% seed set)	Total	χ^2
Short Labelle/ Labelle	Tall	26 (33)	52 (45)	78	
	Short	22 (15)	14 (21)	36	8.18**
	Total	48	66	114	
Short Labelle/ Lebonnet	Tall	34 (43)	49 (40)	83	
	Short	24 (15)	5 (14)	29	
	Total	58	54	112	15.10**

** Significant at the 0.01 probability level, with 1 df.

Table 6. Mean performance of Labelle and Short Labelle in 2 yrs of replicated trials.

			Yield†									
			1981 Arkansas Rice Performance Test					1982 Cooperative Regional Uniform Rice Nursery				
Identity	Height	Heading date	Clay Co.	Keiser*	Marianna	Pine Tree*	Avg	AR*	LA*	MS	TX*	Avg*
	m	days	kg ha^{-1}									
Labelle	1.12	80	7640	7120	6870	6490	7028	5940	7370	5650	5700	6180
Short Labelle	0.89	82	7780	6030	6550	3990	6090	4930	6390	5220	4900	5360

* Values in the column are significantly different at the 0.05 probability level. † At 12% moisture.

be the case for SLBL is still unknown, but because SLBL is similar to LBLE in its resistance to rice diseases, amylose content, alkali reaction, and milling yields, SLBL has potential as a blast resistant, nonallelic, U.S. long-grain source of semidwarfism for rice varietal improvement.

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